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By

Thomas William McMahon, Jr.

2001

ABSTRACT

The purpose of this prospective cohort study was to investigate the relationship between static anthropometric measures or demographical information and overuse injuries in the lower leg, ankle and foot. Lower leg, foot and ankle injuries have always been a problem for military recruits. Loss of duty time, expensive rehabilitation costs and dismissal from active military duty have been consequences of these injuries. For the military population, there is a strong need to know not only the benefits but also the short-term risks of exercise. Even relatively benign injuries, such as sprained ankles, can be costly in terms of loss of training time and reduced combat readiness of soldiers. No study to date has investigated the United States Air Force for the purpose of injury prevention.

Ankle and foot anthropometric measurements were taken bilaterally from 204 United States Air Force Academy cadets. Demographic information, fitness level and lower extremity function were also assessed. All subjects were followed for six months and all injuries sustained to the lower leg, ankle and foot were recorded. Chi-square and regression analyses were performed at a level of significance set a priori at $p < 0.05$ for all variables to assess their relationship to injury incidence. Demographic information,

fitness level, lower extremity functional level and six dependent variables measurements were not significantly related to injury after chi-square testing. Binary logistic regression analysis for all variables demonstrated a significant relationship between navicular drop, total talocrural range of motion, total supination, fitness level and injuries to the lower leg, ankle and foot. However, the strength of the correlation was low for all findings, with r square of 0.031 for the navicular drop results and r square of 0.169 for talocrural range of motion, fitness level, and total supination results.

This study provides evidence that many lower leg, foot and ankle morphologic characteristics do not place individuals at increased risk for overuse injury, but that formulas may exist which predict potential for injury. The results of this study suggest that the time consuming screening processes implemented in various athletic and military settings may not be necessary.

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By

THOMAS WILLIAM McMAHON, JR.

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF HEALTH SCIENCE

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CHAPTER 1
INTRODUCTION

A significant amount of duty time is lost and money spent each year on the treatment of lower extremity injuries sustained by active duty military personnel. A high percentage of these injuries are overuse injuries sustained during initial training periods. A question arises concerning whether many of these injuries are preventable. It is imperative that military recruits are healthy to serve the purposes of defense.

Many studies have tried to find a relationship between various factors (anthropometric measures, strength, epidemiology, fitness levels) and overuse injury, but results are conflicting. No military study to date has concentrated on a United States Air Force population.

Approximately half of all sports injuries may be attributed to overuse or repetitive microtrauma rather than to a single traumatic event.[26,28] The etiology of these injuries is multifactorial with contributions from both extrinsic and intrinsic factors. The influence of anatomical factors on overuse injuries is not yet completely understood and existing studies often conflict with one another. Existing studies are correlative and the finding of an association between a specific anatomical factor and an overuse injury is difficult and does not prove cause and effect.[28] Overuse injuries are prevalent in athletes and military recruits, but ankle ligament injuries are the most common injuries in sports and recreational activity.[2,43] Although the ankle sprain is not specifically an overuse injury, it is included in this study because of the extraordinarily high incidence of ankle injuries.

Prevention of overuse injuries is a major goal of health care practitioners. In order to prevent injury, there must be a clear understanding of the normal mechanics of the foot and ankle, causative factors and the mechanisms by which they interact.[8]

The biomechanics of the foot and ankle is important to the normal function of the lower extremity. Pronation and supination are the arthrokinematic movements within the foot and ankle that are essential for proper attenuation of compressive, tensile, shearing and rotary forces during the stance phase of gait.[17] Since the axis of the subtalar joint is oblique with respect to the three cardinal planes of motion at the ankle joint, pronation and supination must be defined in all three planes in both open and closed chain situations. Open chain subtalar pronation consists of eversion, abduction and dorsiflexion of the calcaneus and supination includes inversion, adduction and plantarflexion of the calcaneus. In closed chain subtalar joint pronation, the calcaneus everts and the talus adducts and plantarflexes whereas supination is comprised of calcaneal inversion, and talus abduction and dorsiflexion.[17] Abnormal pronation and supination can be described as a hyper- or hypo-mobility within the joints of the foot and ankle, often as compensation for soft tissue and/or bone abnormalities. Compensations occur normally, often at the subtalar joint, to allow the foot to function correctly during the gait cycle. If the compensation is persistent, pathology often occurs. While a certain degree of pronation and supination during gait is required for shock absorption and foot stability, respectively, restricted or excessive pronation or supination predisposes individuals to lower extremity injury in the ankle and foot.[17] In normal running, the foot strikes the ground in a supinated position with subsequent forefoot pronation, relative to the rearfoot, and return to supination at toe-off. Any deviation from this pattern caused

by intrinsic biomechanical abnormalities may predispose an individual to overuse injuries of the foot and ankle.[23]

Risk factors for any injury may be classified as extrinsic or intrinsic.[8] Extrinsic factors are characteristic of the environment in which the individual participates. Potential extrinsic factors for overuse injuries include training methods and equipment, such as inadequate footwear, the training surface, faulty biomechanics and training errors.[28] Intrinsic factors are associated with characteristics of the individuals themselves. Intrinsic factors can be muscular, mechanical, hormonal or nutritional. Injuries may occur as a result of the summation of various extrinsic and intrinsic factors at a given point in time. A combination of extrinsic and intrinsic factors can predispose individuals to develop overuse injuries. Difficulty in understanding the causes of risk factors result because, often, combinations of and interactions between risk factors are possible.[8]

Overuse injuries develop when repetitive stress to bone and musculotendinous structures damages tissue at a greater rate than that at which the body can repair itself.[28] The tissue is continually injured on the microscopic level and cannot repair itself as rapidly as the damage is being done. The level of force that a given tissue can withstand may be increased by gradually increasing the training load, improving flexibility and strength, improving sport or training related biomechanics, and correcting anatomical malalignment.[28]

Anatomic Factors Associated With Overuse Injuries

Anatomical factors related to overuse injuries can be divided into two categories: bony factors and soft tissue factors. Bony factors relate to the alignment of the extremity and the geometrical configuration of components of the skeletal system. If health care

practitioners can recognize bony factors predisposing the athlete to overuse injury, other controllable risk factors, such as training errors and environmental factors, may be avoided. Soft tissue factors relate to muscle, tendon and ligament and affect joint range of motion. Flexibility deficits, as well as ligamentous laxity, may also predispose individuals to overuse injuries.[28]

Shin Splints or Medial Tibial Stress Syndrome

Controversy exists about the definition of shin splints. According to Gooch et al.[23] the term may be described by being limited to deep posterior calf muscle group insertion inflammation and periostitis, leading to medial distal leg pain. Shin splints is a nonspecific term that has been applied to a wide variety of disorders that cause pain in the lower leg. The tibial stress fracture is often initially identified as a shin splint. In a review article by Gooch et al.[23] intrinsic and extrinsic factors related to shin splints were identified. Intrinsic factors that may predispose to shin splints include muscle tightness, weakness of the posterior tibialis and the long toe flexors, and lower extremity malalignment. Lower extremity malalignment may include a hypermobile pronated foot, increased heel eversion, tibia varum and forefoot or hindfoot varus. Extrinsic factors include running on hard surfaces, rapid increases in mileage or speed, and running in poorly cushioned shoes.

Although there is some question as to the etiology of shin splints, some authors have indicated that unaccustomed eccentric action of the plantar flexors, especially the soleus, is a major precipitating factor.[5] There is also the claim that the tibialis posterior is the primary muscle involved.[45] Because the specific tissues that are involved with shin

splints are still in dispute, the term medial tibial stress syndrome (MTSS) imparts a nonspecific but descriptive label to the affliction.

According to Andrish,[1] MTSS refers to an overuse injury producing an inflammatory soft tissue reaction and pain along the posteromedial border of the tibia in the middle and distal third of the leg. On examination, individuals have a diffuse area of tenderness along the posteromedial border of the tibia. Bone scan images show a diffuse area of moderately increased radionuclide uptake. These observations help differentiate MTSS from tibial stress fractures, which have a more focal area of severe tenderness and greatly increased radionuclide uptake on bone scan.[1]

The tissue source of pain involved with MTSS was initially credited to the origin of the tibialis posterior muscle. An anatomical study has shown that the site of pain and increased uptake on bone scan corresponds to the origin of the medial soleus, not the tibialis posterior, on the tibia.[35] The medial soleus is the main dynamic, as well as static, controller of ankle plantar flexion and it also inverts the calcaneus. During running, it contracts eccentrically to limit pronation.[12] Saxena et al.[45] dispute this information in a dissection study to support the theory of involvement of the tibialis posterior. The authors concluded that the tibialis posterior arises from the distal third of the tibia, becoming a potential contributor to MTSS. In another cadaver study, Beck and Osternig[3] support the role of the soleus as the major contributor to MTSS. They dissected the legs of 50 cadavers in an attempt to identify accurately the structures that attach to the tibia at the site of symptoms of MTSS. The soleus and the flexor digitorum longus were found to attach most frequently at the site where symptoms of MTSS occur. In no specimen did

they find the tibialis posterior to attach to this site along the distal one-half to one-third of the medial border of the tibia.[3]

The primary anatomical factor associated with MTSS is excessive pronation. In a study by Vitasalo and Kvist,[52] which quantified the degree of subtalar pronation, a relationship was established between the degree of pronation and the severity of shin splints. It was found that runners with MTSS pronate more at heel strike than those without it. Excessive pronation increases the eccentric work that must be done by the medial soleus. This excessive pronation may be caused by other factors, such as leg length discrepancy or tight Achilles tendon.[52]

One study assessed leg length, Q angle, hamstring flexibility and ankle flexibility in those with MTSS and found most of these factors to be insignificant in relation to injury.[34] The researchers revealed an association between maximum pronation, maximum pronation velocity decreased dorsiflexion motion and MTSS. Nonanatomical factors which may lead to MTSS are sudden changes in training intensity, and changes in footwear, running surfaces and terrain.[28] In a retrospective study Sommer and Vallentyne[50] searched for a relationship between the incidence of MTSS and the degree of forefoot to hindfoot varus. It was found that both hindfoot and forefoot varus alignment occurred more often in cases of MTSS than in controls. They determined that a standing foot angle of less than 140 degrees could serve as an accurate threshold for assessing the risk of MTSS. In the procedure, the researchers measured the standing foot angle while weightbearing as the angle between the medial malleolus-navicular prominence and the navicular prominence-first metatarsal head segments.[50]

Anterior Compartment Syndrome

Compartment syndrome can lead to exercise-induced pain in the lower leg.[23] Although any of the four compartments of the lower leg (anterior, lateral, deep posterior, or superficial posterior) may be involved, the anterior compartment is the most frequently involved. It is believed that pain is caused by ischemia due to an increased intracompartmental pressure from muscular swelling during exercise. Neurovascular compromise may occur in severe cases.

During running, the ankle dorsiflexors contract eccentrically absorb impact forces and to prevent foot slap in individuals who land on the rearfoot.[5] These eccentric contractions contribute to an increase in compartment pressure. Beckham et al.[5] compared the anterior compartment pressure in cyclists and runners at equivalent workloads. Anterior compartment pressure measured after maximal exercise was significantly greater in runners as compared to cyclists.

Plantar Fasciitis

Plantar Fasciitis is an overuse injury commonly seen in individuals involved in running sports. The plantar fascia is a fibrous connective tissue originating from the medial tuberosity of the calcaneus and inserting on the proximal phalanges. It acts as a truss maintaining the medial longitudinal arch of the foot and assisting with shock absorption during weight bearing activities.[16] Plantar fasciitis is an inflammation of the fascia at or just distal to its insertion into the medial calcaneus.[23] Individuals with plantar fasciitis experience pain at the medial tubercle of the calcaneus and have tenderness with palpation in that area. The tenderness often extends along the entire medial portion of the plantar fascia.[16]

Several anatomical factors have been associated with plantar fasciitis. These include excessive pronation, cavus foot type, and leg length discrepancy. Excessive pronation increases the tension placed on the plantar fascia during weight bearing.[16] Achilles tendon tightness has been associated with causing compensatory excessive pronation related to plantar fasciitis. One study found that the majority of athletes with plantar fasciitis lack more than five degrees of ankle dorsiflexion with the knee extended.[27] Pes cavus can cause plantar fasciitis since the cavus foot is often rigid, lacks the ability to absorb shock and adapt itself to the ground and has a "windlass" effect, increasing the stress on the plantar fascia. Leg length discrepancy may contribute to the development of plantar fasciitis by causing compensatory excessive pronation on the side of the short leg.[28]

Stress Fractures

The most severe overuse injuries are stress fractures, most commonly occurring in the tibia and tarsal bones.[28] A stress fracture is a partial or complete fracture of a bone resulting from its inability to withstand stress applied in a rhythmic, repeated, subthreshold manner. It is a common injury in physically active individuals, particularly runners and military recruits.[8] The most common site for a stress fracture is the tibia, followed by the tarsal bones and then the metatarsals, usually the second and third.[32]

According to Morris et al.,[39] repetitive strains are essential for the maintenance of normal bone strength, and physical activity can lead to increased bone mass as bone adapts to the additional loads placed upon it. Bone can also lose strength as a result of repetitive loads occurring during normal daily activities. This loss of bony strength is attributed to the formation and propagation of microscopic cracks within the bone. If the

load is continually applied, microdamage accumulates. Repair does not occur where remodeling cannot maintain the integrity of the bone and these microscopic cracks can develop into a stress fracture. According to Schaffler et al.,[46] the processes of microdamage accumulation and bone remodeling, both resulting from bone strain, play an important role in the development of a stress fracture. They report that the stress fracture may ultimately occur because the microdamage is too extensive to be repaired by normal remodeling, because depressed remodeling processes cannot adequately repair normally occurring microdamage, or because of a combination of these factors. It is possible that some stress fractures are secondary to high magnitude repetitive loads, which result in a loss of the structural integrity of bone.[46] An association between various factors influencing skeletal alignment and stress fractures has been sought in military populations.

In a review by Bennell et al.,[8] it is stated that the structure of the foot helps determine how much force the foot will absorb and how much is transferred to bone during ground contact. They state that the high arched foot, pes cavus, is more rigid and less able to absorb shock, resulting in more force passing to the tibia and femur. The low arched foot, pes planus, is more flexible, allowing stress to be absorbed by the musculoskeletal structures of the foot. This type of more flexible foot is less stable during weight bearing which may contribute to muscle fatigue as the muscles have to work harder to control the excessive motion, especially at toe-off. Pes planus can also be associated with prolonged pronation, or hyperpronation, which may induce excessive torsion of the tibia. Either foot type may be a contributing factor for stress fractures.[8]

Other alignment features which have been assessed in relation to stress fractures are leg length discrepancy, genu valgum, genu recurvatum, increased Q angle, and tibial torsion. Of these, only leg length discrepancy and Q angle have been found to have an association with stress fractures.[7,11,14,15]

Leg length discrepancy has been theorized as a possible risk factor for stress fractures due to resulting skeletal realignment and asymmetries in loading, bone torsion, and muscle contraction.[15] Correlational findings have been reported in a cross-sectional survey of male and female runners.[11] In this survey the results of a self-administered questionnaire revealed that those who claimed to have a leg length difference were more likely to have sustained a stress fracture.[11] In another study, 70% of women who developed stress fractures displayed a leg length difference of more that 0.5 cm. This was compared with 36% of women without stress fractures.[7]

Body size and soft tissue composition could affect stress fracture risk by influencing the forces applied to bones.[8] As bodyweight is positively related to ground reaction force, heavier individuals would generate higher forces during physical activity. This could theoretically increase the likelihood of a stress fracture. Body size may be more of a risk factor in military recruits where size variations are likely to be greater than in athletes. In one study, the incidence of stress fracture was greater in smaller individuals. The authors commented that this may be because of common training requirements where similar weight packs and other equipment are carried regardless of recruit bodyweight.[4]

The role of flexibility and joint range of motion in contributing to stress fracture is difficult to evaluate since they encompasses a number of characteristics including active

joint mobility, ligamentous laxity and muscle length.[8] Flexibility of muscles and joints may directly influence stress fracture risk by altering the forces that are applied to bone.

Skeletal muscle may play a role in stress fracture development. Muscle weakness or fatigue could predispose an individual to stress fracture by causing an increase or redistribution of stress to bone.[6] Scott and Winter[47] calculated that during running, the tibia is subjected to a large forward bending moment as a result of ground reaction force. The calf muscles work to oppose this bending moment by applying a backward moment as they contract to control the rotation of the tibia and the lowering of the foot to the ground with the effect of a smaller bending moment. A stress fracture could potentially develop if the calf muscles were unable to produce an adequate eccentric force to counteract the loading at ground contact and decrease excessive bone strain.[47]

Several other variables have been assessed for their relationship with stress fracture development: pes cavus, leg length differences, Q-angle, lower extremity flexibility, hip range of motion, female menstrual cycles, use of oral contraceptive pill, and lack of physical fitness (see subheading Military Studies).[7,10,11,13,14,20-22,24,25,36,38,48,51,53]

Posterior Heel Pain

Posterior heel pain in individuals may be related to a number of pathologic conditions, the most common of which are Achilles tendonitis, Achilles tenosynovitis and retrocalcaneal bursitis. These disorders are related to a cavus foot, poor shoes or gastrocnemius/soleus insufficiency.[29]

The Achilles tendon, the peritenon which encloses this tendon, or both, may become inflamed. An area 2 to 6 cm above the tendon insertion is least vascular and

most susceptible to inflammation and rupture.[23] The most prominent hypothesis regarding etiology is that the rapid and repeated transitions from pronation to supination during running cause the Achilles tendon to undergo a "bow-string" or "whipping" action. If overpronation exists, this action results in a "wringing" or twisting action, causing added stress to the Achilles tendon. Other theories include microtearing caused by rapid shortening and lengthening of the calf musculature, poor ankle flexibility/tight calf muscles, and excessive training. Excessive rearfoot motion was the most common mechanism believed to cause the onset of Achilles tendonitis.[33]

Ankle Sprains

Ankle Sprains are the single most prevalent injury sustained in the body.[31] Eighty-five percent of ankle injuries are sprains, and approximately 85% to 95% of these are inversion sprains, injuring the lateral ligament complex. Medial ligament eversion sprains or deltoid ligament sprains constitute 5% to 6% of ankle sprains, and syndesmosis sprains account for the remaining injuries.[31]

Lateral ankle injuries usually occur when the body's weight lands on the plantar-flexed and internally rotated ankle.[5] Injuries result from supination and inversion of the foot with external rotation of the tibia on the fixed foot.[44] In a review article, Safran et al.[44] describe lateral ankle injuries: the foot is twisted medially in relation to the lower leg, resulting in a progression of tears in a predictable sequence. As the ankle moves from dorsiflexion to plantar flexion, bony stability decreases and the ligamentous contribution to ankle stability proportionally increases.[44] The bony stability of the ankle joint mortise decreases at foot strike when the foot is plantar flexed and supinated.[31] This causes a decrease in the talar weight-bearing surface where the articular surface is not

fully loaded and the ligaments absorb added stress. Common examples include a poorly executed cutting maneuver, landing on an irregular playing surface and landing on a competitor's foot.[31]

The anterior talofibular ligament is the most susceptible to injury and in two thirds of cases is the first and only ligament injured in an ankle sprain.[23] Other injuries that may be associated with ankle sprains include fifth metatarsal or fibular fractures, tibiofibular syndesmosis disruption, peroneal tendon subluxation, and deltoid ligament disruption.[23]

Intrinsic and extrinsic risk factors for ankle sprains are the same as for overuse injuries. Several studies have attempted to identify predisposing factors for ankle injury.[2,17,37] Baumhauer et al.[2] prospectively examined intrinsic risk factors for inversion ankle sprains in college-aged athletes. The risk factors measured were demographic information, ligamentous stability of the ankle, ankle muscle strength, anatomic foot and ankle alignments, and generalized joint laxity. The researchers examined each of these risk factors before the athletic season and investigated if a deficit in one or a combination of these factors would identify an individual or a specific ankle at risk for an inversion ankle injury. No significant differences were found between the injured and uninjured groups in any of the factors measured. The only finding was that individuals with a muscle strength imbalance as measured by an elevated eversion-to-inversion ratio exhibited a higher incidence of inversion sprains.[2]

In an extensive examination of foot and ankle biomechanics, Donatelli[17] suggested that individuals with pes cavus deformities might be prone to ankle sprains. He found that these subjects were unable to pronate their feet adequately and had

decreased calcaneal eversion. He theorized that they are unable to adapt to changes in terrain surfaces, leaving the ankle more vulnerable to an ankle sprain.[17]

Previous history of ankle injury has been found to associate with recurrent sprains.[9,18,37] One study found that individuals with a previous history of an ankle sprain with damage to the lateral ligament complex are two to three times more likely to sustain a subsequent ankle injury.[18] The researchers in another study stated that after an inversion ankle sprain, the evertor musculature can remain weak for more than 10 years.[9] The muscles crossing the ankle joint, such as the peroneal muscles, function as dynamic stabilizers of the ankle and assume an important role when the static stabilizers are compromised.[9] Positive history of an inversion ankle sprain was identified as a predictive factor of subsequent ankle injury in a study of military recruits.[37] The researchers suggested that prior injury to the lateral ligament complex may result in a deficiency in its role as a static stabilizer of the ankle.

Military Studies

Most studies involving military recruits relate to stress fractures. Several military studies have indicated that the risk of a stress fracture is greater for male recruits with pes cavus than with pes planus. It has been reported by Giladi et al.,[22] in a study using military recruits to compare arch heights and injury incidence, that the overall incidence of stress fractures in the low-arched group was 10%, compared to 40% in the high-arched group. Foot type was, however, assessed in a non-functional position, and recruits with extreme pes planus were excluded from the study. Trainees with average arches had an incidence of stress fractures of 31%, similar to the high-arched group.[22] Despite these flaws, the findings of this study were supported in another study where recruits with high

arches were more likely to have sustained a stress fracture than those with lower arches.[10] Montgomery et al.[38] obtained profiles of the feet by visually inspecting and classifying arches as cavus, neutral, or planus. No significant differences were noted between the groups and the researchers concluded that foot geometry did not possess a predictive value for subsequent injuries.[38] In a prospective study, femoral and tibial stress fractures were found to be more prevalent in the presence of feet with high arches, whereas the incidence of metatarsal fractures was higher in low arched feet.[49]

Leg length discrepancy has been theorized as a possible risk factor for stress fractures due to resulting skeletal realignment and asymmetries in loading, bone torsion, and muscle contraction.[15] One study, using male military recruits, failed to show a relationship between leg length differences and the likelihood of stress fractures.[14] The results of other studies, however, have suggested a correlation. Using radiological methods to assess leg length in standing, it was found that in 130 cases of stress fractures in military recruits, the longer leg was associated with 73% of tibial, metatarsal and femoral fractures, and 60% of fibular fractures were found in the shorter leg.[20] In a prospective analysis following a group of 102 parachutists over 330 days, observations revealed a positive association between the degree of leg length inequality and the incidence of stress fractures.[20] Incidence percentages were noted as follows: 15.4% in those with equal leg lengths, 24.3% in those with a 5 to 9mm difference, and 67.7% in those with a 1.5 to 2.0 cm difference.[11] Similar findings have been reported in a cross-sectional survey of male and female runners. Results of a self-administered questionnaire revealed that those who claimed to have a leg length difference were more likely to have sustained a stress fracture.[11] In another study,[7] 70% of women who developed stress

fractures displayed a leg length difference of more that 0.5 cm. This was compared with 36% of women without stress fractures.[7]

Military recruit strength may be associated with the development of stress fractures. A study that tested the general leg strength of recruits found that those who were one standard deviation below the population mean for both absolute and relative maximal leg press strength had a 5 times greater risk for stress fracture than stronger recruits.[24]

There is speculation as to the relationship of Q angle to stress fractures. Using computer digitization to calculate the Q angle of 294 male recruits, those with a Q angle of greater than 15 degrees had a relative risk of stress fracture that was 5.4 times greater than recruits with an angle less than 15 degrees.[14]

Several variables have been assessed pertaining to flexibility including range of rearfoot inversion/eversion, ankle dorsiflexion/plantar flexion, knee flexion/extension, and hip rotation/extension together with length of lower extremity musculature.[25,36,38] Of these, only range of hip external rotation[36] and range of ankle dorsiflexion[25] have been associated with stress fracture development.

In a study of Israeli soldiers, those with hip external rotation greater than 65 degrees were at a higher risk for tibial and total stress fractures than those with a range less than 65 degrees. The risk for tibial stress fracture increased 2% for every one-degree increase in hip external rotation.[36]

In a cross-sectional study of 47 male recruits, restricted ankle dorsiflexion was related to an increased risk of metatarsal stress fracture. Those with a decreased range were 4.6 times more likely to develop a metatarsal stress fracture.[25]

There is suggestion that stress fractures are more common in women with menstrual disturbances. In a cohort study of 101 female Marines, the incidence of stress fractures in those with fewer than 10 periods per year was 37.5% compared with 6.7% in those with 10 to 13 periods per year.[53] Conversely, in a study of 49 female soldiers with stress fractures and 78 soldiers with no injuries, menstrual patterns did not differ between groups. [13] Although some authors have claimed that the oral contraceptive pill may protect against stress fractures by providing an extra source of estrogen to reduce the remodeling bone rate and improve bone density, literature fails to confirm this. Two prospective studies, one in athletes and one in female Marines, have failed to support a protective effect of the oral contraceptive pill use on stress fracture development.[7,53]

Lack of prior physical activity and poor physical conditioning may predispose individuals to stress fractures. Most of the literature focuses on military recruits, during initial training, subjected to short bursts of intense, unaccustomed activity, who are often unfit. Self-reported previous physical activity is the usual means of obtaining fitness level. Although the data are conflicting, the majority of studies tend to suggest that physical fitness or prior physical activity may be a predictor of stress fracture risk in individuals undergoing basic military training.[8]

One study reported that male trainees with a running history averaging at least 25 miles per week in the previous year had a lower incidence of stress fracture than trainees averaging less than 4 miles per week.[38] In another study,[21] 3025 Marine recruits were observed for 12 weeks. A strong trend was identified of decreasing stress fracture injury rates by history of increasing physical activity. The researchers found the stress fracture rate to be 24 times greater in the previously inactive group than in the very active group.

In a prospective study in female Marines, those who reported running less than 2.8 miles per session had a 16.3% incidence of stress fractures during basic training compared with 3.8% who ran more than 2.8 miles per session.[53] In another study of female military recruits, higher leisure activity energy expenditure tended to be associated with a lower stress fracture risk.[13] Shaffer et al.[48] developed a screening tool to identify individuals at high risk for lower extremity stress fracture when beginning a rigorous physical training program. A group of 1078 United States Marine Corps recruits where asked five physical activity questions and given a 1.5 mile run, and 21.6 % of high risk subjects (those individuals with low levels of recent physical activity) suffered more than three times as many stress fractures to the tibia, foot, fibula, and heel as low risk subjects. The authors concluded that the data suggested that risk of stress fracture during rigorous physical training is increased by poor physical fitness and low levels of physical activity prior to their entry into the program.[48] Conversely, in a study of 295 male recruits,[51] aerobic fitness was measured by calculating the predicted VO2/max in addition to self-reporting pretraining participation in sports activities. Neither VO2/max nor pretraining was found to be related to stress fractures.

The incidence of inversion ankle sprains in military recruits was examined in a study focusing on intrinsic and extrinsic risk factors.[37] The researchers found that extrinsic factors, such as boot or shoe type, did not affect the incidence of injury, but intrinsic factors, especially previous history of inversion sprains were found to be risk factors in this population.

Aspects of the training regimen can play a role in the development of stress fractures. Military studies have shown that various training modifications can decrease

the incidence of stress fractures in recruits. Modifications include rest periods, elimination of running and marching on concrete, use of running shoes rather than combat boots and reduction of high impact activity.[8]

Hypotheses

The purpose of this study was to investigate the relationship between static anthropometric measures and demographical information and overuse injuries in the lower leg, ankle and foot. For the purposes of this study, the following research hypotheses were investigated.

1. Excessive pronation will have a significant relationship with lower leg, ankle and foot injuries. Messier and Pittala[34] found a higher incidence of shin splints in subjects with excessive pronation. DeMaio et al.[16] report a relationship between excessive pronation and plantar fasciitis.

2. Large navicular drop values will have a significant relationship with lower leg, ankle and foot injuries. Navicular drop has shown to be an indicator of pronation at the foot.[40] This being true, high navicular drop values should coincide with excessive pronation, reiterating hypothesis number one.

3. Poor physical condition will have a significant relationship with lower leg, ankle and foot injuries. Montgomery et al.[38] found that male trainees with an active running history prior to training had a lower incidence of stress fracture. Cline et al.[13] reported that subjects with higher leisure activity energy expenditure had a lower stress fracture risk. Gardner et al.[21] identified a trend of decreasing injury rates with history of increasing physical activity. Shaffer et al.[48] reported that risk of stress fracture during

rigorous physical training is increased by poor physical fitness and low levels of physical activity prior to their entry into the program

4. Decreased ankle dorsiflexion will have a significant relationship with lower leg, ankle and foot injuries. Messier and Pittala[34] found that dorsiflexion range of motion was less in subjects with shin splints. Hughes[25] found a an association between stress fractures and decreased dorsiflexion motion.

5. Decreased calcaneal eversion will have a significant relationship with lower leg, ankle and foot injuries. Donatelli[17] found that subjects with decreased calcaneal eversion had a higher incidence of ankle sprains.

6. Individuals with increased body weight will have a significant relationship with lower leg, ankle and foot injuries. Frederick and Hagy[19] theorized that overuse injuries would be greater in heavier individuals. Since bodyweight is positively related to ground reaction force, these individuals would generate higher forces during physical activity.

CHAPTER 2
METHODS

Subjects

The study sample consisted of 204 cadets from the United States Air Force Academy with mean age of 19.7 years with standard deviation of 1.83 years. All subjects were enrolled in the Air Force Academy and included cadets from freshmen through senior year. Subject procurement involved a cadet wide email requesting voluntary participation in the study. Inclusion criteria comprised of any United States Air Force Academy cadet who was a student through the spring 2001 semester. As long as the cadet was on full duty status at the time of testing, he/she was permitted to participate, regardless of prior injury. Exclusion criteria comprised of any lower extremity condition or injury which prevented normal function at the time of testing or any other condition or injury, such as back problems, which interfered with normal lower extremity function. All 204 subjects completed the study. In the study, individual subject confidentiality was strictly maintained by use of numeric codes. No information regarding specific cadets is provided. Prior to beginning the study, University of Florida and Air Force Academy Institutional Review Board forms for human subject use was submitted and approved.

Instrumentation

Two plastic goniometers, one with level attached and one without, one six inch plastic ruler, and non-permanent markers were used during the initial data collection. All

data measured was logged onto a Subject Data Sheet (Appendix A). All data were entered into an SPSS file via coding system.

Procedure

The study was a prospective cohort study involving cadets enrolled in the United States Air Force Academy. The study lasted seven months. A physical therapist was responsible for anthropometric measurements. Pre-injury demographic information and post-injury data was obtained by self-report.

Anthropometric and epidemiological data for this study were gathered during the month of August 2000, during the summer training session at the United States Air Force Academy. Follow-up injury data was gathered from September 2000 to February 2001 via e-mail questionnaires.

Prior to participation in the study, each subject read and signed a University of Florida and an Air Force Academy informed consent document. Each subject then filled out a self-administered preliminary questionnaire (Appendix B). Age, gender, race, height, weight, history of trunk and/or lower extremity injury, previous and current fitness level and athletic history were recorded for each subject.

Seven anthropometric measurements were collected on both legs of each subject: navicular drop, ankle dorsiflexion, ankle plantar flexion, ankle inversion, ankle eversion, tibial torsion, and full supination.

Intrarater reliability was assessed for each anthropometric measurement using a test-retest method on 15 subjects. Static measurements were repeated on the same subject, on the same day, approximately 30 minutes apart. Intrarater reliability was found to be adequate for all measures, with the lowest reliability coefficient calculated at 0.874.

Navicular Drop

The navicular drop test was used as a clinical measure of pronation. The distal most point of the navicular tuberosity was marked on the medial side of the foot. Each subject began this test by sitting with his or her subtalar joint palpated in the neutral position. Palpation of subtalar neutral was performed by palpation of the talar head on both the medial and lateral side of the joint. The height of the navicular was measured from the floor to the distal most point on the navicular bone. Subjects then stood, with the foot in a relaxed position. The navicular distance was measured again. The difference between the two navicular distances was calculated. A difference value of 6 mm was considered normal, greater or equal to 9 mm was considered high, and values less than 6 mm was considered low.[32]

Tibial Torsion

Tibial torsion was measured as a value of thigh foot angles using a goniometer. The subject was asked to lie supine on a plinth with the hips in neutral rotation and the knees fully extended, feet off the plinth. Thigh foot angle was measured with the foot first in subtalar neutral, then with the foot in full supination. The fulcrum of the goniometer was centered over the center of the heel of the foot, midway between the malleoli. The proximal arm was aligned over the first ray perpendicular to the floor, ensured by use of a level attached midway on the proximal arm. The distal arm was aligned over the plantar surface of the anterior midline of the second metatarsal.

Ankle Range of Motion

Ankle range of motion was measured using a goniometer. The subject was placed in a seated position at the end of the plinth, lower leg hanging over the edge. The fulcrum of the goniometer was centered over the lateral aspect of the lateral malleolus. In

the starting position, the proximal arm of the goniometer was aligned with the lateral midline of the lower leg, using the head of the fibula as a reference point. The distal arm of the goniometer was aligned parallel to the fifth metatarsal. The ankle was positioned so that the goniometer read 90 degrees. This was considered the neutral position for the ankle. Ankle dorsiflexion and plantarflexion were recorded from this position. Inversion and eversion ranges of motion were assessed from the subtalar joint. The subject was positioned prone with the hip in neutral rotation, knees fully extended and the foot placed over the edge of the plinth. The fulcrum of the goniometer was centered over the posterior aspect of the ankle, midway between the malleoli. The proximal arm was aligned with the posterior midline of the lower leg and the distal arm with the posterior midline of the calcaneus.[42]

Injury Documentation

Once a month for 6 months following the initial assessment (September 2000 to February 2001), each subject was emailed a follow-up Injury Tracking Form (Appendix C) to inquire about sustained injuries. Type, incidence and cause of injury were documented on this form. If the subject did not sustain an injury, they were instructed to reply to the email with the response "no" attached. If the subject did sustain an injury, they were instructed to fill out the attached questionnaire and forward it to the researchers. Subject injury data was input into an SPSS document via coded system.

Injuries were classified via five digit coding system following guidelines from NAIRS Medical Terminology Codes.[30] The first two digits of a diagnosis code identify the body part involved. The third digit provides a description of what happened to the

body part. The fourth and fifth digits provide a more precise diagnosis if the information is available.

Injury was defined as: the injury kept the cadet out of training, exercise or competition on the day following the injury, and/or the injury required medical attention of any kind beyond icing or wrapping. Data was recorded only if it was training, exercise or sports related. Exclusion criteria consisted of contusions, inconsequential injuries such as minor muscle strains with no visible swelling, ecchymosis, weakness, skin lacerations or abrasions.

Data Analysis

The dependent variables in this study were demographical information, pre-testing fitness level, level of lower extremity function, and static anthropometric measures. The independent variables were the lower leg, ankle and foot injuries. A Pearson chi-squared test and binary logistic regression were performed for all data analysis. The significance level was set up at $p<0.05$.

Chi –square analysis was used to detect differences of the dependent variables between the two groups (injured and uninjured). It was used to measure how close the observed frequencies were to the expected frequencies.

Individual chi-square tests were performed in cross tabulations between "injury status" and each of the following: age, gender, year/degree, race, current physical fitness, exercise frequency during the past year, previous post injury return of function to 100%, current level of lower extremity function, birth control use, regular/irregular menstrual cycle. Injury status constituted whether or not a subject sustained a lower leg, ankle or foot injury.

Chi-square tests were performed to assess whether or not differences existed between the proportions of lower leg, ankle or foot injuries and static anthropometric measures. The injured lower extremities were tested against each of the following anthropometric measures: right and left navicular sit heights, right and left navicular stand heights, right and left navicular drop values, right and left ankle dorsiflexion, right and left ankle plantar flexion, right and left total talocrural motion, right and left ankle eversion, right and left ankle inversion, right and left total inversion to eversion motion, right and left thigh-foot angle, right and left thigh foot angle position in full pronation, and right and left total pronation motion.

Binary logistic regression analysis was performed to attempt to describe how the probability of injury incidence depends on the values of each explanatory variable. The explanatory variables tested against injury incidence included all demographic information and all anthropometric measures. Two mechanical, stepwise, binary logistic regression data analysis equations were used to relate anthropometric and demographical variables to injury of the right and left legs.

CHAPTER 3
RESULTS

Demographic Data

Two hundred and four cadets from the United States Air Force Academy (Colorado Springs, Colorado) participated in this study. A total of 156 (76.5%) male and 48 (23.5%) female subjects were included. The subject group was comprised of cadets from the freshman, sophomore, junior and senior classes. The majority of subjects, 57.9%, were sophomore and junior students. Sophomores constituted 30.4%, and juniors 27.5%, of the subject pool. Freshmen and senior subjects accounted for 19.6% and 22.5% of the subject population, respectively. Ages of subjects ranged from 17 to 25 years (mean age: 19.7) of whom 53.4% were 19 and 20 years old. For the remaining subjects, 17.2% of them were under 19 years of age and 29.4% were older than 20 years. Mean height and weight for males was 180.34 cm and 77.02 kg, respectively, and for females was 152.4 cm and 62.78 kg, respectively. For ethnicity, 84.8% of the subjects were caucasian, 7.8% Hispanic, 2.9% African American, 2.0% Asian, and the remaining 2.5% were classified as other.

Several aspects of perceived current fitness and function levels were asked of each subject on the preliminary questionnaire. For current fitness level data, subjects were asked, "how would you rate your current physical fitness?" The mode response to this question was: "very good" (Table 3-1). For exercise frequency data, subjects were then asked, "during the past year, how often did you exercise or play sports?" The mode

response to this question was tied between: “five times per week” and “six times per week” (Table 3-2). Subjects were asked if they had sustained lower extremity injuries in the past, and, if yes, asked if they were able to return to full function. Of the 156 subjects who had sustained prior injury, 85.3% reported that they have been able to return fully to the level of physical activity maintained before injury. When subjects were asked to rate their current level of lower extremity function on a scale of 0% to 100%, 89.2% rated their function at 90% or greater. Derived from the initial questionnaire, 83.3% of the females reported experiencing normal menstrual cycles and 39.6% reported that they were currently using birth control

Table 3-1

Response Frequencies to the Question: “How would you rate your current physical fitness?”

Response	Frequency	Percent
Fair	8	3.9
Good	62	30.4
Very Good	98	48.0
Excellent	36	17.6
Total	204	100.0

Table 3-2

Response Frequencies to the Question: "During the past year, how often did you exercise or play sports?"

Response (Times per week)	Frequency	Percent
1or less	4	2.0
2	10	4.9
3	35	17.2
4	41	20.1
5	48	23.5
6	48	23.5
7	18	8.8
Total	204	100.0

Anthropometric Data

To provide normative data, the means and standard deviations for the following seven anthropometric measures were calculated: Navicular drop, dorsiflexion, plantarflexion, eversion, inversion, thigh-foot angle, and total supination (Table 3-3). Eversion and inversion motion was measured from the rearfoot. Total supination was measured as the total range of motion obtained from the summation of the thigh-foot angle at subtalar neutral and the thigh-foot angle at full supination. Histograms for these measures displayed approximately normal "bell-shaped" curves. At the time of data collection, the right and left lower extremity of each subject was measured for a total of 408 limbs tested.

Table 3-3

Means and Standard Deviations for Navicular Drop (cm) and Ankle Range of Motion Measures (degrees)

Anthropometric Measures	Mean (Standard Deviation)
Navicular Drop	0.98 (0.38)
Dorsiflexion	16.95 (6.47)
Plantarflexion	68.4 (8.53)
Eversion	1.1 (2.28)
Inversion	22.2 (6.34)
Thigh-Foot Angle	6.5 (2.41)
Total Supination	32.0 (7.42)

Comparative data was obtained between the injured and non-injured groups (Table 3-4). The mean and standard deviation for every anthropometric measure taken for the right and left lower extremities were obtained. For each extremity, the data from subjects with injuries to the lower leg, ankle and foot were compared to non-injured subject data. All anthropometric values collected are within normal ranges of motion for this type of subject group.[41]

Table 3-4

Means (Standard Deviations) Comparing Injured versus Non-Injured Data for Navicular (cm) and Ankle Range of Motion (degrees) Measurements

Anthropometric Measure	Injured Leg		Non-Injured Leg	
	Right	Left	Right	Left
Navicular Sit Height	4.91 (0.58)	4.58 (0.71)	4.94 (0.45)	4.46 (0.54)
Navicular Stand Height	3.78 (0.67)	3.71 (0.88)	4.06 (0.44)	3.33 (0.71)
Navicular Drop Height	1.13 (0.40)	0.87 (0.37)	0.88 (0.29)	1.13 (0.30)
AnkleDorsiflexion	17.92 (7.98)	19.55 (22.40)	18.08 (5.22)	16.00 (6.43)
Ankle Plantarflexion	69.96 (8.75)	61.82 (5.62)	68.23 (5.92)	69.14 (5.97)
Ankle Talocrural Motion	87.88 (11.93)	51.73 (51.11)	86.31 (7.66)	75.57 (35.55)
Ankle Eversion	2.19 (3.15)	0.27 (0.90)	1.38 (1.89)	1.14 (1.83)
Ankle Inversion	22.23 (7.64)	26.73 (8.37)	20.00 (3.61)	26.71 (7.78)
Total Inversion/Eversion	24.42 (9.46)	27.00 (8.57)	21.38 (4.89)	27.86 (8.23)
Thigh-Foot Angle	7.23 (1.90)	5.82 (1.17)	7.23 (2.92)	5.71 (1.33)
Thigh-Foot Angle in Full Supination	25.04 (7.22)	27.10 (8.47)	22.77 (5.67)	27.29 (5.72)
Total Supination	32.27 (7.52)	32.91 (9.02)	30.00 (6.82)	33.00 (5.82)

Table 3-5 displays the injury nature frequencies. Of the 54 injuries sustained to the lower leg, ankle and foot, the predominant injuries were ankle sprains and shin splints, which accounted for 55.6% and 31.5% of the total injuries, respectively. Of the 30 ankle sprains sustained, 96.7% of them were inversion sprains. Injuries to the ankle accounted for 59.3% of the 54 injuries that occurred during the study, and was the most

frequently injured body part. The lower leg was the next most frequently injured body part, accounting for 35.2% of all injuries, followed by the foot at 5.5%.

Injury reporting by cadets may be of interest to the Academy. Of the 54 injuries occurring to the lower leg, ankle and foot, only 18 injuries (33%) were reported to a health care provider, leaving the remaining 36 injuries (67%) going untreated by a professional.

Table 3-5.

Frequency Table for Total Injuries Sustained During Data Collection Classified by Injury Nature

Injury Nature	Frequency	Percent
Inversion Ankle Sprain	29	53.7
Shin Splints	17	31.5
Calf Strain	2	3.6
Achilles Tendonitis	2	3.6
Plantar Fasciitis	1	1.9
Eversion Ankle Sprain	1	1.9
Midtarsal Sprain	1	1.9
Metatarsal Stress Fracture	1	1.9
Total	54	100.0

Chi-Square Analyses

Individual chi-square tests were performed in cross tabulations between "injury status" and each of the following: age, gender, year/degree, race, current physical fitness, exercise frequency during the past year, previous post injury return of function to 100%,

current level of lower extremity function, birth control use, regular/irregular menstrual cycle (women only). Injury status constituted whether or not a subject sustained a lower leg, ankle or foot injury. Chi –square analysis was used to detect differences in proportions of each of the variables, indicating whether it is likely that the variables are associated. It was used to measure how close the observed frequencies were to the expected frequencies assuming that the variables were independent. None of the above chi-square tests were found to be significant at $p<0.05$.

Chi-square tests were performed to detect differences of the dependent variables between the two groups (injured and uninjured). The injured lower extremities were tested against each of the following anthropometric measures: right and left navicular sit heights, right and left navicular stand heights, right and left navicular drop values, right and left ankle dorsiflexion, right and left ankle plantar flexion, right and left total talocrural motion, right and left ankle eversion, right and left ankle inversion, right and left total inversion to eversion motion, right and left thigh-foot angle, right and left thigh foot angle position in full supination, and right and left total supination motion. None of the above chi-square tests were found to be significant at $p<0.05$.

Binary Logistic Regression

Binary logistic regression analysis was performed to attempt to describe how the probability of injury incidence depends on the values of each explanatory variable. The explanatory variables tested against injury incidence included all demographic information and all anthropometric measures. Two mechanical, stepwise, binary logistic regression data analysis equations were used to relate anthropometric and demographical variables to injury of the right and left legs. Two final equations were created from this

analysis. The first equation was the result of testing all independent variables against right lower leg, foot and ankle injures. Significance was found at $p = 0.047$ with Nagelkerke r square of 0.031. This equation was calculated as:

$$\text{Logit (Proportion Right)} = -2.363 + 0.938 \text{ Left Navicular Drop.}$$

The second equation was the result of testing all independent variables against left lower leg, foot and ankle injuries. In step 3 of the stepwise analysis, significance was found as follows: $p = 0.035$ for Left Total Talocrural Motion, $p = 0.036$ for Right Total Supination, and $p = 0.002$ for Physical Fitness Level. The Nagelkerke r square for this equation was 0.169. This equation was calculated as:

$$\text{Logit (Proportion Left)} = -7.173 + 0.951 \text{ Fitness Level} + 0.071 \text{ Right Total Supination} - 0.012 \text{ Left Total Talocrural Motion.}$$

By placing values into each equation, a likelihood ratio for injury is provided. Potentially, the odds of an individual sustaining an injury are determined. The value obtained by solving the equations gives the probability that a randomly selected individual will sustain an injury.

CHAPTER 4
DISCUSSION AND CONCLUSIONS

In the present study, the relationship between static anthropometric measures, epidemiological information, and overuse injuries in the lower leg, ankle and foot were investigated. By collecting the pertinent information outlined in this study, assessments were made between each of the data collected and injury status.

One of the benefits of this study was the generating of demographical information on Air Force Academy cadets. No study to date has collected this type of information on the Air Force. Demographics on age, height, weight, exercise frequency, perceived fitness level, perceived lower extremity function, birth control use, menstrual regularity may be useful in comparing information on future studies pertaining the Air Force. One of the more important findings was the large number of injuries that were not reported to a health care professional. Possible reasons for this shortcoming of reported injuries are that the cadets are afraid of losing training time, ego, or lack of knowledge of the potential harm of leaving an injury untreated. Failure to report injuries can cause inaccurate epidemiology reports.

In accordance with other literature stating that ankle sprains are the most commonly occurring injury,[31] this study has also demonstrated that ankle sprains are most prevalent. Out of 54 injuries to the lower leg, ankle and foot, 55.6% of the injuries sustained in this study were ankle sprains. In the literature, most of the injuries occurring during the initial training periods were stress fractures and shin splints.[4,14,22,24,36]

Although shin splints were among the most common injuries sustained during the present study, only one incidence of a stress fracture was noted.

Chi –square analysis was used to detect differences of the dependent variables between the two tested groups (injured and uninjured). Individual chi-square tests were performed on cross tabulations between "injury status" and each of the following: age, gender, year/degree, race, current physical fitness, exercise frequency during the past year, previous post injury return of function to 100%, current level of lower extremity function, oral birth control use, and regular/irregular menstrual cycle (women only), and the anthropometric measurements. Chi-square analysis revealed no significant difference between the injured and uninjured subjects for these variables. A reason for not finding significance may be that chi-square analysis is not the most appropriate testing procedure. Information may be missed by linearly analyzing the data. Regression may be a better approach where a more realistic response curve is generated, capturing more data. Another reason for not finding significance is that there were not enough injuries to be analyzed.

Binary logistic regression analysis was performed to investigate how the probability of injury incidence depends on the values of each explanatory variable. The explanatory variables tested against injury incidence included all demographic information and all anthropometric measures. The equations created from these analyses can be used as a predictive tool for injury. By putting the appropriate anthropometric values into each equation, a likelihood ratio for injury is provided.

The analysis resulted in left navicular drop being a significant factor for right lower extremity injuries, thus suggesting that left navicular drop values are somehow

related to injury of the right lower leg, ankle and foot. This may be suggestive of a compensatory reaction, since left anthropometric measures are influencing right sided injury. To compare these results with those from other studies, the suggestion that navicular drop and pronation are related to injury agrees with results from Messier and Pittala,[34] where a higher incidence of shin splints was seen in subjects with excessive pronation. In addition, DeMaio et al.[16] reported that a relationship exists between excessive pronation and plantar fasciitis.

Perceived fitness level, right total supination, and left total talocrural motion were noted as significant factors for left lower leg, ankle and foot injury. Hence, fitness level may have an impact on whether an injury will occur. With respect to right total supination, a compensatory component may be applicable, since the formula suggests that right total supination has an effect on left sided injury. Finally, according to the generated equation, left total talocrural motion (the summation of dorsi- and plantarflexion) influences injury to the left lower leg, ankle and foot. The finding that fitness level has an impact on injury is consistent with information from several studies.[13,21,38,48] Montgomery et al.[38] found that male trainees with an active running history prior to training had a lower incidence of stress fracture. Cline et al.[13] reported that subjects with higher leisure activity energy expenditure had a lower stress fracture risk. Gardner et al.[21] identified a trend of decreasing injury rates with history of increasing physical activity. Shaffer et al.[48] reported that risk of stress fracture during rigorous physical training is increased by poor physical fitness and low levels of physical activity prior to their entry into the program.

Birth control use and menstrual cycle regularity were unrelated to injury. This is consistent with a study of 49 female soldiers in which menstrual patterns did not differ between injured and uninjured groups.[13] These results also agree with two other studies that did not find a relationship between contraceptive pill use and injury development.[7,53]

Based on the findings of this study, the following conclusions can be made about the hypotheses. It cannot be rejected that excessive pronation, large navicular drop, and poor physical condition share some relationship with lower leg, ankle and foot injuries. Not enough data was extracted from the results of the study to state that decreased ankle dorsiflexion is an indicator of injury. The results of the current study do not support the hypotheses that decreased subtalar eversion and increased body weight are related to injuries to the lower leg, ankle and foot.

The significant findings of the present study need to be noted with caution since the r squares for both equations were low. Although the correlation coefficients are low, the results agree with the findings in other studies.[13,16,21,34,38,48]

A plausible conclusion is that the anthropometric measures used in this study are not reliable in predicting injury. Measurements similar to the ones performed in this study are routinely used in screening sessions. It may be not be necessary to take the time to conduct this sort of screening. Another plausible conclusion is that formulas created from this study are true predictors of potential for injury. If formulas like these are confirmed to be true indicators of injury, the end result could be the development of parameters to decrease injury. A preventative rather than a reactive approach toward injury has the potential of saving the military money with decreased costs in treating

patients, saving care-giver time, and most importantly, maximizing military readiness status.

Several problems, limitations and areas to be improved upon were discovered during the course of the study. Subjects in this study were not random, they were volunteers. Since more volunteers were available than could be tested, an attempt was made to randomly select subjects among the volunteers. Although comparisons were made and data tested against right and left lower extremities, it was not noted which leg of each subject was the dominant or skill side. Clearer conclusions could have been made if this information was documented. Due to a limited amount of time each cadet was permitted to volunteer, the researcher taking measurements took only one reading for each measured item. Subjects were not divided into groups, such as by sports, so a wide variety of subjects were tested. Initially, the researchers desired to test only freshmen prior to any training. Due to limitations in the number of subjects, all classes needed to be included. The freshmen in this study were tested approximately one month after entry into the Air Force Academy. Although the freshmen subjects were not exposed to any rigorous training at that early time, there was still some mandatory running and marching during the time period before we tested them. This allowed some conditioning prior to our testing the subjects, which may have altered the flexibility or injury status of the cadets. Since training had begun prior to the initiation of the study, some freshmen may have already sustained an injury, excluding them from participation.

A few weaknesses became apparent affecting data analysis as the study progressed. All injuries used in this study were self-reported via email. Since many injuries were left untreated by health care professionals, the injury pool would have been

too small to conduct the study if analysis were limited to reported injuries only. If more time was available for data collection, a larger number of subjects could have been used. If more time was available to track subjects, a much larger number of injuries may have been obtained. Another potential weakness of the study, was trying to predict injury due to dynamic activity via static measurements.

The importance of this study is that it is the first of its kind conducted on Air Force Academy cadets. The study can serve as a template, stepping stone, or as pilot data from which future studies can stem. If so desired, the data obtained in this study can be used to create a longitudinal study to be conducted over several years so that enough injury data is collected to draw stronger conclusions. With the improvements in study design, valuable information may be obtained in the prevention of injuries to the lower leg, ankle or foot. Once variables that predispose injury are identified, the designing of implementation procedures for injury prevention can occur. Certain foot and ankle variables, certain types of training practices, and certain issued equipment may predispose an individual to injury. If these variables are found to be a potential for injury, measures can be taken to address them.

APPENDIX A
SUBJECT DATA SHEET

NAME: ____

	Right		Left	
Navicular Drop:	___	___	___	___
Ankle Dorsiflexion:	___		___	
Ankle Plantarflexion:	___		___	
Ankle Eversion:	___		___	
Ankle Inversion:	___		___	
Thigh-Foot Angle: subtalar neutral	___		___	
full supination	___		___	

APPENDIX B
PROJECT QUESTIONNAIRE

Name:

Age:

Academic Year:

Male: Female:

Race: Caucasian African-American Hispanic Asian Other(specify)

Weight/Height

Did you play sports in High School? Y/N What sports?

How would you rate your current physical fitness? (circle one)
1-Poor 2-Fair 3-Good 4-Very Good 5-Excellent

During the past year, how often did you exercise or play sports: (circle one)
Never 1x or less per week 2x per week 3x per week
4x per week 5x per week 6x per week 7x per week

Have you had injuries to any of the following: (Approximate date of injury and brief description/diagnosis in space provided)

Hip	Knee
Ankle	Foot
Hamstring	Quadriceps
Calf	Shin

Following any injuries occurring to date, were you able to return to 100% of the level of physical activity you had maintained prior to the injury? (circle one)

0- Does not apply. I have never injured bone, muscle, tendon, ligament, or cartilage in one or both of my lower limbs

2- No, as a result of at least one injury, I have never been able to perform at 100% of the level of physical activity I had maintained before I was injured

3- Yes, I have been able to return fully (100%) to the level of physical activity I had maintained before I was injured.

Rate your current level of lower extremity function, on a scale of 0 – 100 ("0" being total immobility and "100" being completely functional).

FEMALES:

Are you on Birth Control? Y/N

Are your menstrual cycles regular? Y/N

APPENDIX C
INJURY TRACKING FORM

APPROXIMATE DATE OF INJURY

WHICH LEG DID YOU HURT: RIGHT____ LEFT____ BOTH____

WHICH ACTIVITY DID INJURY OCCUR (mark with an x)

a-recreational sport___ b- military training___ c-exercise____ d-daily activity_____

ON WHICH SURFACE DID INJURY OCCUR

a-not applicable___ b-grass___ c-wood___ d-concrete___ e-stairs___

f-dirt/cinders___ g-asphalt___

WHICH CATEGORY MOST CLOSELY DESCRIBES THE ACTIVITY WHICH CAUSED INJURY

a-collision/person___ b-collision/object___ c-turning/twisting___ d-overuse___

e-stretching___ f-running____ g-other (please specify):

DID INJURY REQUIRE TREATMENT BY PROVIDER? Yes___ No____

If Yes, what was the name of your injury/diagnosis?

WHICH LIMB/JOINT WAS INJURED (Please give brief description of injury)

Hip____ Groin____

Quadriceps___ Hamstring___

Knee ____ Shin____

Calf____ Ankle____

Foot____

Briefly Describe in your own words what happened and what you think the injury is (ie. sprained knee/ankle, torn ligament, muscle strain)

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BIOGRAPHICAL SKETCH

Thomas W. McMahon, Jr. is originally from Long Island, New York. He received his Bachelor of Science degree in physical therapy from Daemon College in New York in 1993. Thomas was commissioned into the United States Air Force, as a second lieutenant, after graduation from Daemon College. His first military duty title was Staff Physical Therapist at Andrews Air Force Base in the Washington, D.C., area. He was next stationed at Nellis Air Force Base in Las Vegas, Nevada, where he was the Assistant Element Chief of physical therapy services. He was selected by the Air Force Biomedical Corps to achieve his Master of Health Science degree at the University of Florida. He currently holds the officer rank of Captain. At the completion of his graduate degree, Thomas will be stationed at Buckley Air Force Base in Denver, Colorado. There, he will help develop a physical therapy department from the ground up. Once the clinic is functional, he will be the Element Chief in charge of physical therapy services.